VII. *A comparison of the diurnal changes of intensity in the dipping and horizontal needles, at Port Bowen.* *By* LIEUTENANT HENRY FOSTER, *R. N. F. R. S. Communicated February 25, 1826.*

THE following comparative observations on the intensity of the dipping and horizontal needles, were made with a particular object in view, which will be proper to explain before giving the details.

It was found by observation, that the intensity of the horizontal needle was hourly varying: this appeared by the results already given to this Society in a former paper: but it was doubtful, whether this variation of horizontal intensity of a needle, proceeded from an actual variation in the intensity of the terrestrial magnetism, or from a variation in the amount of its direction, as indicated by the dip itself.

The power of the horizontal needle varying as the cosine of the dip, a change to the amount of a few minutes in the dip, at places where it is very great, would be sufficient to explain all the variations of intensity observed in the horizontal needle, without supposing any change to have taken place in the intensity of the terrestrial magnetic force.

The variation in dip, however, if it did occur, was too small to be detected by direct observation; and I failed also, to render it sensible by the application of magnets, as stated in a former communication.

My object therefore in making the experiments contained

in the following Table, was to ascertain, by several series of vibrations made with the same needle, mounted alternately as a dipping needle, and as a horizontal one, whether or no a corresponding variation of intensity would manifest itself in these two positions respectively; as ought to be the case, if the diurnal changes of intensity in the horizontal needle proceeded from a general change of intensity in the terrestrial magnetic power. But on the other hand, if the force indicated by the dipping needle should be found to remain constant, then it would be equally clear, that the variations of intensity in the horizontal needle proceeded from an actual change of dip only.

As this question is of considerable importance in the theory of terrestrial magnetism, I regret that I had not an opportunity of making a more extended series of experiments of this kind; but, as far as they go, they certainly appear to indicate, that the alterations of intensity in the horizontal needle, are due rather to a daily change in the amount of the dip, than to any variation in the general intensity of the earth's magnetic force; although some change in this also is observable by the vibrations of the dipping needle This explanation of the cause of the change of horizontal intensity, it may be remarked, is consistent with the observations made in Europe, which likewise show an alteration of intensity in the horizontal needle during the day, but in a much less degree than at Port Bowen. Now, if the variation in question really proceed from a change of dip, to the amount of 3, 4, or 5 minutes of a degree, the change of intensity in the horizontal needle will be less and less obvious, as the dip decreases; but if it proceed from a change in the actual intensity of the earth's

magnetism, it ought to be constant in all parts of the world, which is contrary to observation.

In making these experiments, a dipping apparatus by DOLLOND, belonging to the Board of Longitude, was used. This instrument had a needle $11\frac{1}{2}$ inches in length, of an oblong shape, and rounded at its extremities; it was placed in the magnetic meridian, on a pedestal built of stones, and thus afforded the means for ascertaining the variations of intensity in the earth's magnetism, as indicated by the vibrations of the dipping needle. But as I had not a suitable apparatus for ascertaining the variations in horizontal intensity with the same needle; a cubical box 12 inches high was prepared, for which I was indebted to the kindness of Captain HOPPNER. This box had glass ends, to admit of the vibrations of the needle being observed, and contained at the bottom a horizontal circle, divided to every 5 degrees, for the purpose of measuring the arc of vibration; it was likewise fitted with a contrivance, by which the needle could be made to vibrate in any arc at pleasure, and the top was so constructed as to allow the suspension of the needle, to be placed directly over the centre of the circle. The suspension consisted of a few fibres of floss silk, attached to one of the extremities of the axis of the needle, just sufficient to sustain its weight, and several inches in length, to lessen the effects of torsion. This box was also mounted on a pedestal, similar to the one on which the dipping apparatus stood, and both were protected from the weather by being placed in a house built of snow. For observing the horizontal vibrations of this needle, a small telescope, having a vertical wire fixed in the focus of the eye-piece, was placed on a stand firmly frozen to the

ground, at the distance of about eight feet from the middle of the box, in the direction of the magnetic meridian: when the needle was at rest in its natural direction, a fine thread of light reflected from its end, was bisected by the vertical wire in the telescope; the telescope having a lateral sliding motion for the purpose of accomplishing this adjustment.

In making a set of these observations, the following mode was pursued: the needle being suspended horizontally, the adjustment of the telescope above described was first completed, after which, the needle was made to vibrate at the commencement, in an arc of 60 degrees, by the contrivance already alluded to; the time at which the reflected thread of light passed the wire in the telescope, was noted by means of a chronometer, and also at every tenth vibration following, until one hundred were completed: the needle was then removed from the box, and placed on its axis in the dipping apparatus; the time of its performing one hundred vibrations (commencing as before in an arc of 60 degrees) was in like manner noted; the passage of the central point in this case being determined by means of a lens, fixed over that part of the vertical circle to which the needle pointed, when freely supported on its axis and at rest. In this way all the results in the following Table have been obtained; it may not, however, be unimportant to state, that although the needle, in each of its different positions, always vibrated in the same arc at the commencement, viz. 60 degrees; yet the terminal arc, in either position, generally varied.

The Table is divided into two parts; the first contains the observations on the times of vibration of the needle in its horizontal position; and the second, those on it when used as

a dipping needle. In the first column of each part, is inserted the day of the month ; in the second, the hour and minute at which the observations were commenced ; the third column of each part, contains the mean time in seconds taken by the needle in its different positions, to perform one hundred vibrations ; and in the fourth, is inserted the temperature of the needle at the time of observation.

1st Part, Horizontal Needle.				2d Part, Dipping Needle.			
Date.	Time of Commencement.	Mean time in seconds, of performing 100 vibrations.	Temp. Fah^{t}.	Date.	Time of Commencement.	Mean time in seconds, of performing 100 vibrations.	Temp. Fah^{t}.
1825.	h. m.	s.	°	1825.	h. m.	s.	°
Feb. 12th	A.M. 6 35	2128,6	— 17	Feb. 12th	A.M. 11 58	405,4	— 17½
	10 54	2127,6	— 17		P.M. 0 30	405,7	— 17½
	P.M. 1 32	2079,9	— 17	13th	P.M. 3 41	410,0	— 17½
13th	P.M. 1 42	2103,1	— 17	14th	A.M. 10 34	408,0	— 19½
	2 54	2152,5	— 17½		P.M. 0 12	406,5	— 20
14th	A.M. 11 21	2088,2	— 20		8 33	408,4	— 22
	P.M. 1 14	2067,7	— 20		10 00	409,0	— 21½
	9 00	2086,0	— 22		11 12	408,7	— 21½
15th	A.M. 0 41	2107,0	— 22	15th	A.M. 1 34	411,1	— 22
	10 48	2115,5	— 21		10 32	410,0	— 21
	P.M. 8 44	2064,2	— 23		11 35	409,6	— 21
	10 29	2071,0	— 23		P.M. 8 9	409,2	— 23
16th	A.M. 11 4	2077,4	— 27		9 43	408,7	— 23
17th	A.M. 10 18	2071,0	— 22		11 15	409,2	— 22
	11 12	2058,2	— 21	16th	A.M. 10 38	409,9	— 28
	P.M. 0 29	2079,5	— 20		11 46	409,1	— 27
19th	A.M. 10 18	2092,2	— 22½	17th	A.M. 9 42	409,0	— 22
					11 54	408,5	— 20
					P.M. 1 10	409,0	— 20½
				19th	A.M. 10 00	408,5	— 23
					10 58	408,1	— 22
* Mean		2092,33	— 20½	* Mean		408,65	— 21½

* The dip of the needle resulting from these elements is 87° 48′,8 N.

The above results show, that the mean of all the observed times which the horizontal needle required to make one hundred vibrations was 2092,33 seconds, but that differences appear in these times amounting to 94,3 seconds, or $\frac{1}{22}$ part of the interval; whereas in the dipping needle, in which the mean of the times required to perform one hundred vibrations was 408,65 seconds, the greatest difference is only 5,7 seconds, or $\frac{1}{72}$ part of the interval, which is a much less proportional change than the former. As an additional confirmation, however, that the intensity of the earth's magnetism is not subject to much variation, I have given in the following Table the results of observations I made on it at the same place in November, 1824, January and June, 1825. These exhibit the times in which the needle completed one hundred vibrations in the magnetic meridian, deduced from the mean of the times of its performing four hundred vibrations, with the face of the instrument on each side of the vertical, and the needle reversed on its axis in the two positions.

Date.	Middle Time of Observation.	Mean time in seconds of performing 100 vibrations.	Temperature. Fah^t.
	h. m.	s.	°
November 8th	A. M. 10 20	404,94	— 13$\frac{1}{2}$
January 10th	A. M. 11 45	404,69	— 22
June 27th	A. M. 9 30	406,50	+ 47

These results also show, taking into consideration the different temperatures under which they have been obtained, that little or no change in the intensity took place, notwithstanding the observations were made at different hours of the day, as well as at different parts of the year.

Therefore, as has been stated, the change of intensity in the horizontal needle is due, principally, to a daily variation in the amount of the dip; not to a real change of intensity in the terrestrial magnetic force. This at least appears to be a legitimate deduction from the preceding observations; from which circumstance, and that of the daily variation in the direction of the horizontal needle, we are naturally led to the conception of a small variation in position of the magnetic axis, corresponding to a revolution of the polar point round its mean position as a centre, produced by the action of the sun, on the magnetism of the parts of the earth, successively exposed to its influence. And, moreover, it seems by no means improbable, that the annual variation of the position of the magnetic pole may ultimately be traced to the same universal cause.

I have not attempted to enter into any minute calculations on this subject, but I believe it will be found, that if the radius of the circle, described by the pole of the general magnetic axis of the earth during the day, be supposed to subtend at the centre an angle of 2 or $2\frac{1}{2}$ minutes, it will reconcile, to a considerable degree of precision, nearly all the observations on the daily variation of the direction, and daily change of intensity of the horizontal needle, made both in Europe and within the Arctic Circle. If, also, we suppose the magnetic north pole, during the passage of the sun over its meridian, when lying between the pole of the world and the sun, to advance more to the westward, or in a direction contrary to the rotation of the earth on its axis, than it returns to the eastward, or in the direction of rotation of the earth during the sun's passage over the opposite meridian, when the pole

of the world lies between the magnetic pole and the sun, then it follows, that in some certain number of years the magnetic north pole will perform a revolution from east to west round the pole of the earth, and produce an annual change in the variation of the compass in that direction, which is known to obtain. That this may be the case, is rendered probable, by considering that the sun at present approaches nearer to the magnetic north pole in its southern, than in its northern passage over the meridian, by twice the north polar distance of the magnetic pole; and although the reverse takes place on the south pole, yet, as the sun is longer on the northern than on the southern side of the equator, there will be a preponderance of action to carry the north pole forward to the westward, and consequently the south pole to the eastward, as is supposed to be the case by many eminent philosophers in this country.

However, these observations will, of course, require to be repeated in other parts of the world, before this hypothesis can be considered as fully confirmed by experiment.

In this concluding communication relative to our recent northern magnetic experiments, I beg leave again to express my obligations to Mr. BARLOW and to Mr. CHRISTIE. To Mr. CHRISTIE, for his kindness in permitting the observations on the dip and magnetic intensity to be made in his garden at Woolwich, and for the valuable assistance he rendered me in the equipment of the magnetical instruments supplied to the Expedition. To Mr. BARLOW, I stand indebted in a manner which I find it difficult to describe; indeed it is no more than due to the scientific liberality of this Gentleman to state, that on many occasions, when I have shown him my experiments

on the different magnetical subjects wherein I have been engaged, he has kindly given such a direction to my thoughts, as materially to assist me in arriving at the conclusions I have drawn.

P.S. That the magnetic pole moves in an orbit round the pole of the earth, was first conceived, I believe, by Mr. DERHAM, as appears from the Appendix to Philosophical Essays, in three parts, by R. LOVETT, lay clerk of the cathedral church at Worcester, published in 1766, which was put into my hands by a friend, on mentioning to him the theoretical views advanced in this paper. This Appendix contains a brief theory of the north magnetic pole adopted by him from a passage in DERHAM's Physico-Theology, which I shall transcribe in Mr. DERHAM's own words, who, after stating the various discoveries of NORMAN, GELLIBRAND, and others, proceeds to say; "To these discoveries, I hope the reader "will excuse me if I add one of my own, which I deduced "some years ago, from some magnetical experiments and "observations I made; which discovery I also acquainted "our Royal Society with some time since, *viz.* that as the "common horizontal needle is continually varying towards "the east and west, so is the dipping needle varying up and "down, towards or fromwards the zenith, with the magne-"tick tendency describing indeed a circle round the pole of "the world, as I conceive, or some other point; so that if "we could procure a needle so nicely made, as to point ex-"actly according to its magnetick direction, it would in some

" certain number of years describe a circle of about 13*gr.*
" radius round the magnetick poles northerly and southerly.
" This I have for several years suspected, and have had some
" reason for it too; and three or four years ago, mentioning
" it at a meeting of our Royal Society, they were pleased to
" cause it to be entered in the Journals; but I have not yet
" been so happy to procure a tolerable good dipping needle,
" or other proper one to my mind, to bring the thing to
" sufficient test of experience; as in a short time I hope
" to do, having lately hit upon a contrivance that may do
" the thing."

Mr. LOVETT next proceeds to illustrate Mr. DERHAM's theory by appropriate diagrams, and then to compute the latitude of the magnetic pole from the best recorded observations at the time on the variation of the compass at two well known places. Having thus obtained 13° 51′ for the north polar distance of the magnetic pole, or radius of the orbit which it describes round the pole of the earth, he then fixes the year of no variation of the magnetic needle in London to be 1660, from the observations of Dr. HALLEY in 1672; and from a similar observation by Dr. BRADLEY in 1750, he deduces the longitude of the pole for that time, and by this interval of 90 years, he infers the progressive rate of the pole westerly to be in longitude 7° 7′ 12″ every ten years. With these data he has computed a table of variations of the compass for every ten years between 1660 and 1910, in which he has predicted, with near approximation to what has since been observed, considering the distance of time and want of correct knowledge of its quantity, not only the

amount of the variation, but the year in which the magnetic pole arrives at its maximum westerly position. He also states, that in 1912½ the magnetic pole will again be on the meridian of London, and that it requires 505 years, 215 days, 8 hours, and 24 minutes, to make a complete revolution round the pole of the world.